

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
13 September 2001 (13.09.2001)

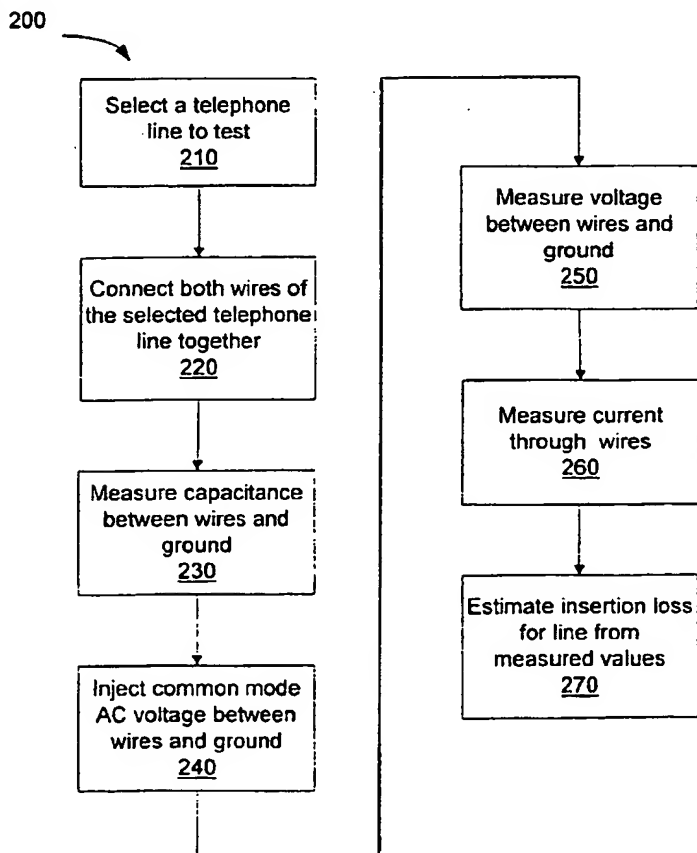
PCT

(10) International Publication Number  
WO 01/67729 A1

- (51) International Patent Classification<sup>7</sup>: H04M 3/30, H04B 3/48 (72) Inventor; and  
(75) Inventor/Applicant (for US only): FAULKNER, Roger [GB/GB]; Stonleigh, Thorn Hill Road, South Marston, Swindon, Wiltshire SN3 4RY (GB).
- (21) International Application Number: PCT/GB01/00936
- (22) International Filing Date: 5 March 2001 (05.03.2001) (74) Agent: LUCKHURST, Anthony, Henry, William; Marks & Clerk, 57-60 Lincolns Inn Fields, London WC2A 3LS (GB).
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: 0005227.4 3 March 2000 (03.03.2000) GB (81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (71) Applicant (for all designated States except US): TERA-DYNE INC. [US/US]; 321 Harrison Avenue, Boston, MA 02118-2238 (US). (84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian

[Continued on next page]

(54) Title: TECHNIQUE FOR ESTIMATION OF A SUBSCRIBER LINE INSERTION LOSS



(57) Abstract: A method and apparatus for pre-qualifying lines with respect to estimating the insertion loss of the line is presented. End-to-end insertion loss at high frequencies is estimated from measurements made at low frequencies through the voice switch at the central office at a telephone company. An AC voltage waveform is applied to the telephone line being tested. Real and imaginary components of the resultant waveform are measured. These measurements are captured and used to estimate the insertion loss of the telephone line at frequencies in the range of 40 kHz to 300 kHz.

WO 01/67729 A1



patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published:**

— with international search report

— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

## TITLE OF THE INVENTION

## TECHNIQUE FOR ESTIMATION OF A SUBSCRIBER LINE INSERTION LOSS

5

This invention relates generally to communication networks and more particularly to systems for qualifying telephone lines for data transmission. As is known in the art, public switch telephone networks, i.e., so-called plain old telephone service (POTS) lines, were originally designed for voice communications, which cover a limited frequency bandwidth (i.e., about 4KHz). Today, it is desired to use the same POTS lines for data transmission. Data signals, however, generally have different frequency characteristics than voice signals. As a result, a POTS line that works well transmitting voice signals might not work well, or at all, for data signals. Telephone companies need to know which lines are suitable, i.e., qualify, and which lines are not suitable for data transmission. Telephone companies also need to know why particular lines are unable to support data transmissions and where such faults occur so they can determine whether the transmission line can be corrected.

There are problems for telephone operating companies (TELCO's) attempting to qualify subscriber loops for delivery of data. One problem is strategic. Telco's are reluctant to deploy emerging technologies for the delivery of data (e.g., ISDN or ADSL) because there is uncertainty in their knowledge that sufficient of the subscriber loops are of high enough quality to make deployment economically successful. This discourages early adopters because there is significant risk in being first to deliver a technology that may not work in their access network. If Telco's could be given a technology to take much of this risk out of initial deployment, they can secure market share and lead in the face of competition

An additional problem is tactical and comes after a Telco has made a decision to deploy a particular technology. There is a need to qualify, either pro-actively or reactively, specific lines for service as that service is requested by subscribers or targeted by the Telco for delivery. Line Qualification is the overall ability to make statements about the quality of

a subscriber loop as it relates to its ability to deliver voice communications (i.e. POTS), or data services. Disqualification is the ability to make a statement with a high degree of confidence that a subscriber loop will not support a data service without remedial actions. Pre-qualification is the ability to make a statement with a high degree of confidence that a subscriber loop will support a data service without remedial actions before attempting to deploy such data services.

When a Telco is able to market and deliver the new service, they would like to target those subscriber loops most likely to support the service out of the box and/or with a minimum of work. As another example, a Telco receiving a new service request from a subscriber desires information to either accept or reject that request for new service based on the condition of the line associated with the subscriber.

A telephone company would like to pre-qualify a line for high data rate operation, such as ISDN and ADSL. Lines that have been pre-qualified can be leased at a higher price. Lines that fail the pre-qualified testing would not be made available for these high data rate services.

With the foregoing background in mind, it is an object of the present invention to provide a method and apparatus for pre-qualifying telephone lines with respect to estimating the insertion loss of the telephone line. End-to-end insertion loss at high frequencies is estimated from single-ended measurements made at low frequencies through the voice switch at the central office of the Telephone Company. An AC voltage waveform is applied to the telephone line being tested. Real and imaginary components of the resultant waveform are measured. These measurements are captured and used to estimate the insertion loss of the telephone line at frequencies in the range of 40kHz to 300 kHz.

The invention will be better understood by reference to the following more detailed description and accompanying drawings in which:

Fig. 1 is a block diagram of a prior art telephone system from a central office to a

customer;

Fig. 2 is a block diagram of the remote measuring unit coupled to the switch test access of the central office; and

Fig. 3 is a flow chart of a method of measuring insertion loss of a telephone line.

5

The telephone network was originally designed for voice communication. Voice communication covers a limited frequency bandwidth. In some cases, telephone lines were optimized for signals within this frequency range (approximately 4 kHz). Even  
10 where the lines were not optimized for voice signals, there was no incentive to make the lines operate at other frequencies and often they did not. Now, it is desired to use those same lines to carry data signals. The data signals generally have different frequency characteristics than the voice signals. As a result, a line that works very well transmitting voice signals might not work well or at all for data signals. Phone companies need to know  
15 which lines will work for data signals and use those lines for data.

Referring to Fig. 1, a prior art portion of a telephone system 10 is shown. The system includes a telephone company central office 20 which has a line extending to a customer 30. The line 40 includes at least two wires, a tip wire and a ring wire which are used to provide communication between the central office and the customer 30. The line  
20 may be comprised of multiple segments 40, 50 and 60. A first segment 40 may be of a particular gauge. A following segment 50 may be of a different gauge than the first segment 40. A third segment 60 may also be of a different gauge than first segment 40 and second segment 50.

There are a number of factors which decrease the end to end data rate attainable  
25 on a pair of wires of a telephone line. Some of these factors are imbalanced lines, contact faults and the like. Given that a telephone line has no other parasitic conditions, the operation of the service on the line ultimately depends on the overall attenuation or insertion loss of the wire pair to the signal applied. Currently telephone companies measure insertion loss by deploying personnel to either end of the wire pair to measure the insertion  
30 loss at different frequencies (e.g. 100 kHz, 300 kHz, etc.) through hand held instruments.

91 This procedure is expensive, labor intensive, and time consuming.

92 Referring now to Fig. 2, a block diagram of the present invention 110 is shown  
93 coupled to a selected telephone line 150. In this embodiment a test unit 110 is located  
94 within the central office 20 of a telephone company. The test unit 110 includes an  
95 interconnection element 115, a voltage measurement element 111, a current measurement  
96 element 112, a capacitance measurement element 113 and a calculation element 114. The  
97 test unit 110 measures the wires 130 and 140 of a selected telephone line 150. The wires  
98 130 and 140 are accessed through a voice switch 120. As such, the test unit 110 may  
99 access a plurality of telephone lines through the switch 120, thus providing measurements  
100 of several telephone lines quickly and easily. By utilizing the voice switch 120, the  
101 injected signals are limited to the voice band, that is up to about 4 kHz.

102 The test unit 110 comprises a hardware/software system specifically developed for  
103 estimating insertion loss of a telephone line. The software includes commands and data  
104 for directing the hardware to perform the various functions such as interconnecting the tip  
105 and ring wires of a telephone line, applying a voltage to a telephone line, measuring the  
106 capacitance of a telephone line, measuring the voltage of a telephone line, measuring the  
107 current in a telephone line, and calculating the estimated insertion loss of the telephone  
108 line. Other functions may also be provided. The test unit 110 also includes storage for  
109 storing the values of the measured variables as well as storing the commands and data  
110 associated with estimating the insertion loss of the selected telephone line.

111 By way of test unit 110, the wires 130 and 140 of the selected telephone line 150  
112 are placed in electrical contact with each other by interconnect element 115. This is done  
113 to cancel any effects that may result from a customer terminating device on the selected  
114 telephone 150. The test unit 110 utilizes the capacitance measurement element 113 to  
115 perform a lumped capacitance measurement of the wires 130, 140 to ground. This  
116 lumped capacitance measurement is made at a low frequency, for example at  
117 approximately 1 kHz or less.

118 The test unit 110 applies a common mode AC voltage between the wires 130, 140  
119 and ground. The test unit 110 utilizes the voltage measuring element to measure the AC  
120 voltage between the wires 130, 140 and ground. The current measuring element 112 is

utilized to measure the driving AC current through the wires. The measured AC voltage is divided by the measured AC current to give the impedance Z.

Test unit 110 utilizes the calculation element 114 to estimate the insertion loss of the selected telephone line at a high frequency, for example 100 kHz, according to the formula:

Insertion loss at 100 kHz =

$$\frac{5000}{\sqrt{(Z^2 + [1/\omega C]^2)}} \text{ dB}$$

Wherein Z is equal to the measured voltage divided by the measured current, C is equal to the measured capacitance, and  $\omega$  is  $2\pi$  times the driving frequency.

The above-described apparatus is useful for performing estimations of insertion loss of a telephone line at a high frequency. The estimation is accomplished by making low frequency single-ended measurements of the line. The measurements can be made at the central office of the Telephone Company and the measurements do not require knowledge of the physical characteristics of the telephone line being measured.

Referring now to Fig. 3, a flowchart showing a method 200 of estimating the insertion loss of a subscriber line is shown. The first step 210 is to select a telephone line to measure. Typically the line is accessed through the voice switch at the central office of the Telephone Company.

The next step, 220, is to connect the tip and ring wires of the selected phone line to each other. This is done to cancel the effects of any terminating device on the selected telephone line.

The following step 230 measures the capacitance between the wires and ground. This measured capacitance value is stored for later use. The capacitance measurement is made at a low frequency such as 1 kHz or less. As such, the measurement can be made through the voice switch at the central office.

At step 240 a common mode AC voltage having a driving frequency of between approximately 2 kHz and approximately 6 kHz, and preferably less than approximately 5 kHz, is applied between the wires of the selected telephone wire and ground. Real and

imaginary components of the resultant waveform will be measured, as described in the following steps.

At step 250 the resultant voltage between the wires and ground is measured and recorded. At step 260 the resultant current flow in the wires is measured and recorded.

5 At step 270 the insertion loss at a high frequency is estimated from the low frequency measurements. The insertion loss of the selected telephone line is calculated according to the formula:

Insertion loss at 100 kHz =

10 
$$\frac{5000}{\sqrt{(Z^2 + [1/\omega C]^2)}} \text{ dB}$$

Where Z is equal to the measured voltage divided by the measured current, C equal to the measured capacitance and  $\omega$  is  $2\pi$  times the driving frequency.

The above-described method provides for performing estimations of insertion loss  
15 of a telephone line at a high frequency. The estimation is accomplished by making low frequency single-ended measurements of the line. The measurements can be made at the central office of the Telephone Company and the measurements do not require knowledge of the physical characteristics of the telephone line being measured.

Having described preferred embodiments of the invention it will now become  
20 apparent to those of ordinary skill in the art that other embodiments incorporating these concepts may be used. Additionally, the software included as part of the tool may be embodied in a computer program product that includes a computer useable medium. For example, such a computer usable medium can include a readable memory device, such as a hard drive device, a CD-ROM, a DVD-ROM, or a computer diskette, having computer  
25 readable program code segments stored thereon. The computer readable medium can also include a communications link, either optical, wired, or wireless, having program code segments carried thereon as digital or analog signals. Accordingly, it is submitted that that the invention should not be limited to the described embodiments but rather should be limited only by the spirit and scope of the appended claims.



## CLAIMS

1. A method of estimating insertion loss of a subscriber line comprising the steps of:  
placing both wires of a selected telephone line in electrical contact with each  
5 other;  
measuring a capacitance between said selected telephone line and ground;  
applying an AC voltage between said selected telephone line and ground;  
measuring a voltage between said selected telephone line and ground;  
measuring a current in said selected telephone line; and  
10 estimating an insertion loss from said capacitance, said voltage and said current.
2. The method of claim 1 wherein said step of measuring a capacitance comprises  
measuring a capacitance at a first frequency.
- 15 3. The method of claim 2 wherein said step of applying an AC voltage comprises  
applying an AC voltage at a second frequency.
4. The method of claim 3 wherein said step of estimating an insertion loss comprises  
estimating an insertion loss at a third frequency.
- 20 5. The method of claim 4 wherein said step of estimating an insertion loss is  
performed according to the formula :

25 
$$\frac{5000}{\sqrt{(Z^2 + [1 / \omega C]^2)}} \text{ dB}$$

wherein Z is equal to said voltage divided by said current, C is equal to said capacitance  
and  $\omega$  is  $2\pi$  times said second frequency.

6. The method of claim 2 wherein said first frequency is less than approximately 1  
30 kHz.

7. The method of claim 3 wherein said second frequency is between approximately 2 kHz and approximately 6 kHz.
8. The method of claim 3 wherein said second frequency is less than approximately 5 kHz.
9. The method of claim 4 wherein said third frequency is between approximately 40 kHz and approximately 300 kHz.
10. The method of claim 9 wherein said second frequency is approximately 100 kHz.
11. The method of claim 1 wherein said method is performed through a switch of a central office.
12. The method of claim 1 wherein said method is performed on-demand.
13. The method of claim 1 wherein said method is performed routinely.
14. The method of claim 1 wherein said steps of measuring a capacitance, measuring a voltage and measuring a current comprise single ended measurements.
15. An apparatus for estimating insertion loss of a subscriber line comprising:  
a connection element placing both wires of a selected telephone line in electrical contact with each other;  
a capacitance measuring element coupled to said connection element and measuring a capacitance between said selected telephone line and ground;  
a voltage source coupled to said connection element and providing an AC voltage between said selected telephone line and ground;  
a voltage measuring element coupled to said connection element and measuring a resulting voltage between said selected telephone line and ground;

a current measuring element coupled to said connection element and measuring a current in said selected telephone line; and

a calculation element in communication with said capacitance measuring element, said voltage measuring element and said current measuring element, said calculation element determining an insertion loss from said capacitance, said resulting voltage and said current.

16. The apparatus of claim 15 wherein said capacitance measuring element measures a capacitance at a first frequency.

17. The apparatus of claim 16 wherein said voltage source provides said AC voltage having a second frequency.

18. The apparatus of claim 17 wherein said calculation element determines an insertion loss at a third frequency.

19. The apparatus of claim 18 wherein said calculation element determines the insertion loss according to the formula

$$\frac{5000}{\sqrt{(Z^2 + [1/\omega C]^2)}} \text{ dB}$$

wherein Z is equal to said voltage divided by said current, C is equal to said capacitance and  $\omega$  is  $2\pi$  times said second frequency.

20. The apparatus of claim 16 wherein said first frequency is less than approximately 1 kHz.

21. The apparatus of claim 17 wherein said second frequency is between approximately 2 kHz and approximately 6 kHz.

22. The apparatus of claim 17 wherein said second frequency is less than approximately 5 kHz.
23. The apparatus of claim 18 wherein said third frequency is between approximately  
5 40 kHz and approximately 300 kHz.
24. The apparatus of claim 18 wherein said third frequency is approximately 100 kHz.
25. The apparatus of claim 15 wherein said capacitance measuring element, said  
10 voltage measurement element and said current measurement element perform single-ended measurements.
26. A computer program product for a test unit, the computer program product comprising a computer usable medium having computer readable code thereon, including  
15 program code comprising:  
instructions and data for causing a processor to perform at least one of interconnecting two wires of a phone line to each other, measuring a capacitance between said phone line and ground, applying an AC voltage between said phone line and ground, measuring a resulting voltage between said phone line and ground, measuring a current of  
20 said telephone line, and estimating an insertion loss of said phone line.
27. The computer program product of claim 26 wherein said instructions and data include commands for measuring a capacitance between the phone line and ground at a frequency of less than approximately 1 kHz.  
25
28. The computer program product of claim 26 wherein said instructions and data include commands for applying an AC voltage having a frequency between approximately 2 kHz and approximately 6 kHz.
29. The computer program product of claim 26 wherein said instructions and data  
30

include commands for applying an AC having a frequency of less than approximately 5 kHz.

30. The computer program product of claim 26 wherein said instructions and data  
5 include commands for estimating an insertion loss of a telephone line between approximately 40 kHz and approximately 300 kHz.

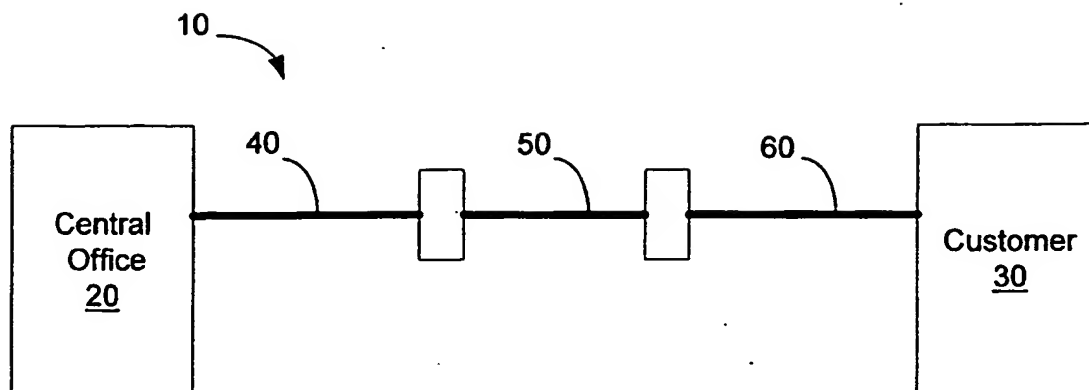
31. The computer program product of claim 26 wherein said instructions and data  
10 include commands for estimating an insertion loss of a telephone line at approximately 100 kHz.

32. The computer program product of claim 26 wherein said instructions and data  
include commands for estimating an insertion loss of a telephone line according to the  
formula:

15

$$\frac{5000}{\sqrt{(Z^2 + [1 / \omega C]^2)}} \text{ dB}$$

wherein Z is equal to said voltage divided by said current, C is equal to said capacitance  
and  $\omega$  is a  $2\pi$  times a driving frequency.



Prior Art

Fig. 1

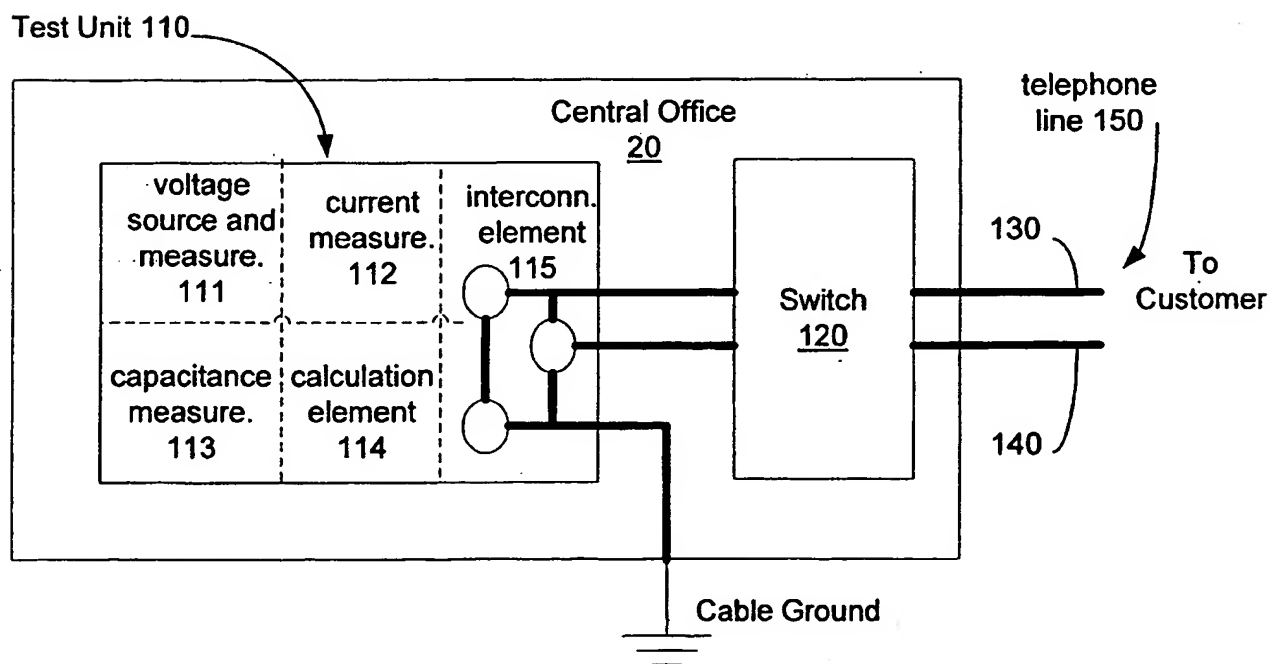
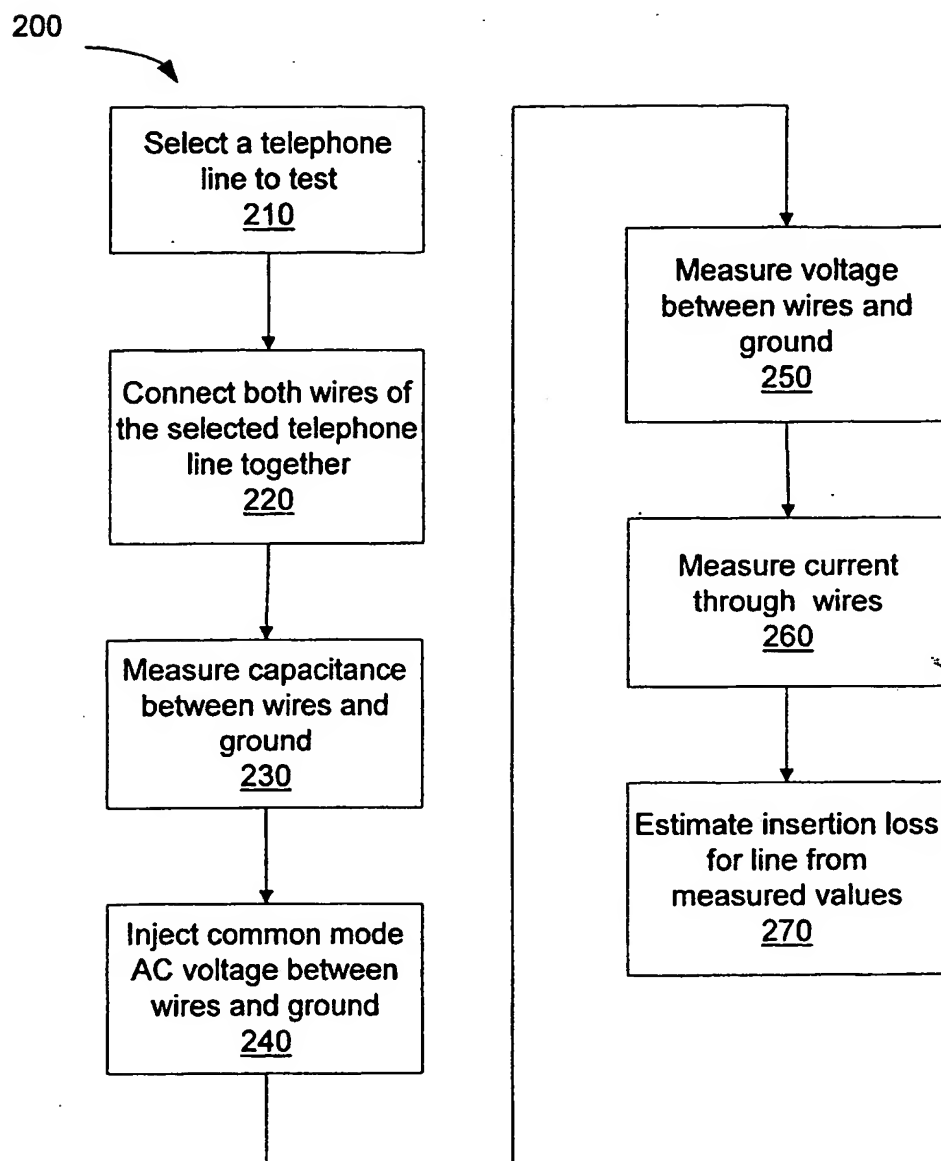


Fig. 2

*Fig. 3*

## INTERNATIONAL SEARCH REPORT

National Application No

NL/GB 01/00936

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H04M3/30 H04B3/48

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H04M H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 864 602 A (NEEDLE JACK) 26 January 1999 (1999-01-26)  column 2, line 10 -column 3, line 13 column 4, line 47 -column 7, line 34 ---	1-4, 6, 8, 11-18, 20, 22, 25-27, 29
A	HEDLUND ET AL: "DSL Loop Test" TELEPHONY, CHICAGO, IL, US, vol. 235, no. 8, 24 August 1998 (1998-08-24), pages 48-52, XP002147002 ISSN: 0040-2656 the whole document --- -/--	1, 15, 26

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

## \* Special categories of cited documents:

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*&\* document member of the same patent family

Date of the actual completion of the international search

12 July 2001

Date of mailing of the international search report

20/07/2001

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Gkeli, M



# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/GB 01/00936

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>EP 0 341 816 A (BRITISH TELECOMM)  15 November 1989 (1989-11-15)  page 2, line 21 -page 3, line 9  page 3, line 21 -page 6, line 14  -----</p>	1,15,26

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 01/00936

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 5864602	A	26-01-1999	US 5978449 A	02-11-1999
EP 0341816	A	15-11-1989	AT 106646 T	15-06-1994
			AU 616251 B	24-10-1991
			AU 3260589 A	19-10-1989
			CA 1311067 A	01-12-1992
			DE 68915614 D	07-07-1994
			DE 68915614 T	13-10-1994
			JP 1311654 A	15-12-1989
			NZ 228702 A	27-11-1990
			US 4924489 A	08-05-1990